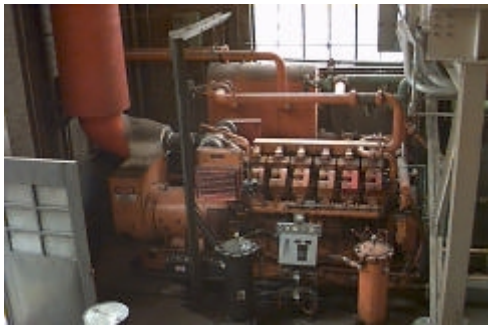
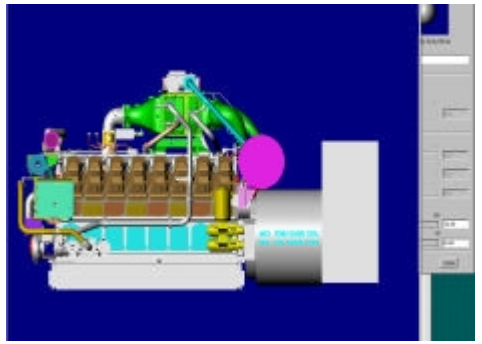
U.S. Department of Energy's Advanced Natural Gas Reciprocating Engine Program

California Advanced Reciprocating
Internal Combustion Engines
Collaborative Workshop



California Energy Commission

July 10, 2001



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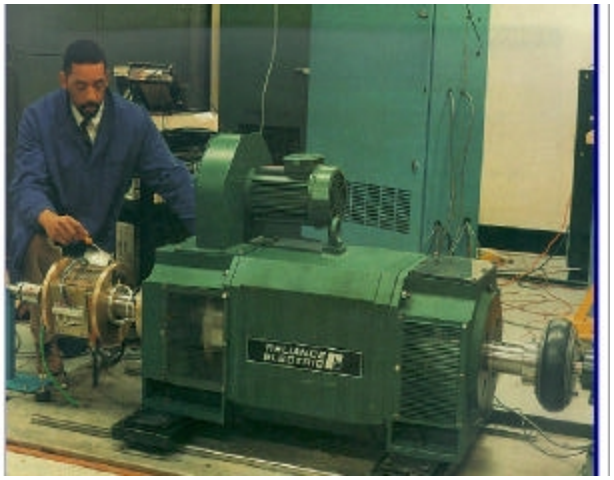
U.S. Department of Energy
Chicago Operations Office

DOE is Working to Expand Distributed Energy Options

- Biopower
- Solar Technologies
- Wind
- Geothermal
- Hydropower
- Hydrogen
- Fuel Cells

- Power Delivery
- Superconductivity
- Transmission Reliability
- Energy Storage
- Smart Controls
- Interconnection Standards

- Natural Gas Turbines
- **Reciprocating Engines**
- Thermally Activated Technologies
- Natural Gas-Renewable Hybrids

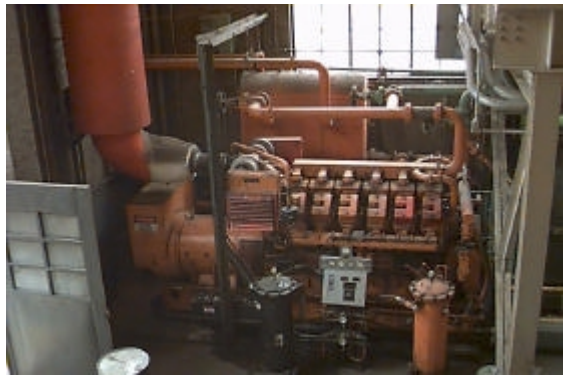


DOE is Developing Technologies for Various Power Ranges

Microturbines
(<1MW)

Fuel cells
(30 – 300 kW)

Gas Turbines
(1-50 MW)



Reciprocating Engines (<10MW)

Primary DOE Goals:
Increase performance; Reduce emissions and cost

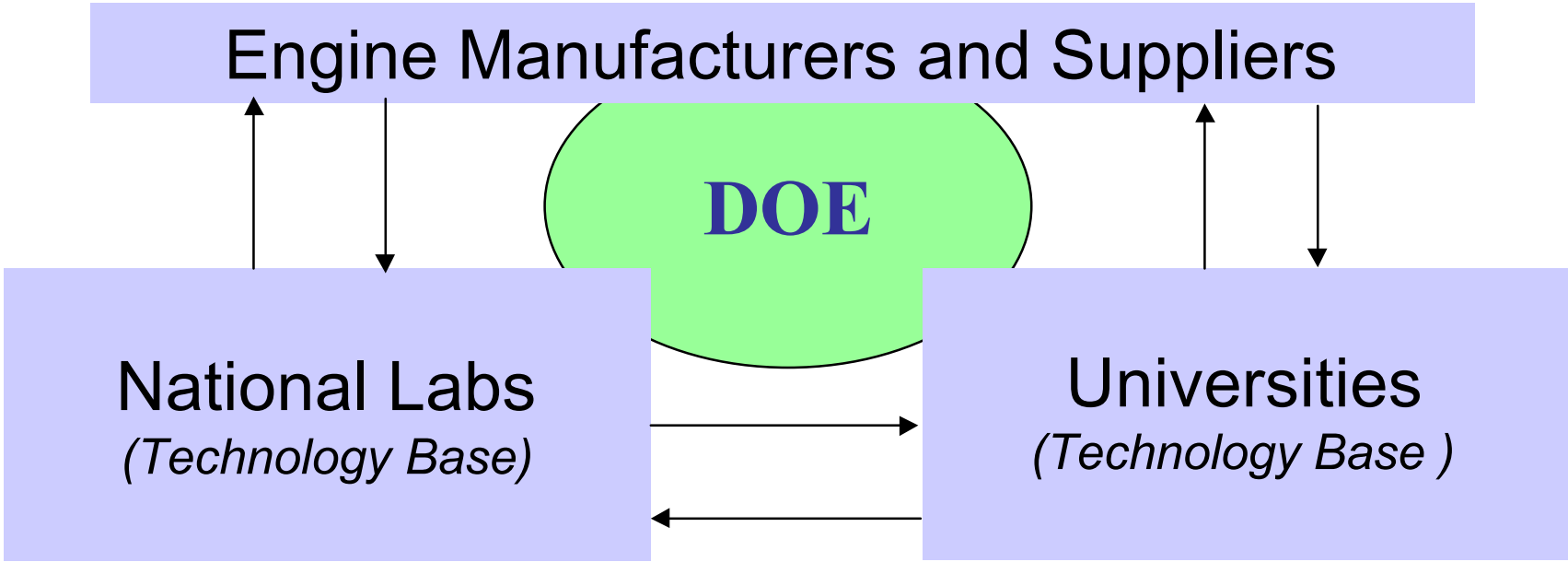
DOE has Established a Collaborative Advanced Engine Program

- **1999 - Joined Southwest Research Institute study commissioned by ARES consortium to determine advanced technology roadmap**
- **Fall 1999 - Conducted DOE workshop to define reciprocating engine program goal and objectives**
- **Currently 7-year program (2000-2006)**
- **DOE Funding Profile:**
  - FY00 - $2.5 M
  - FY01 - $3.0 M
  - FY02 - $3.0 M (Request); Current Markups +$8 M

DOE Program Goal is a Commercial Engine by 2010 with:

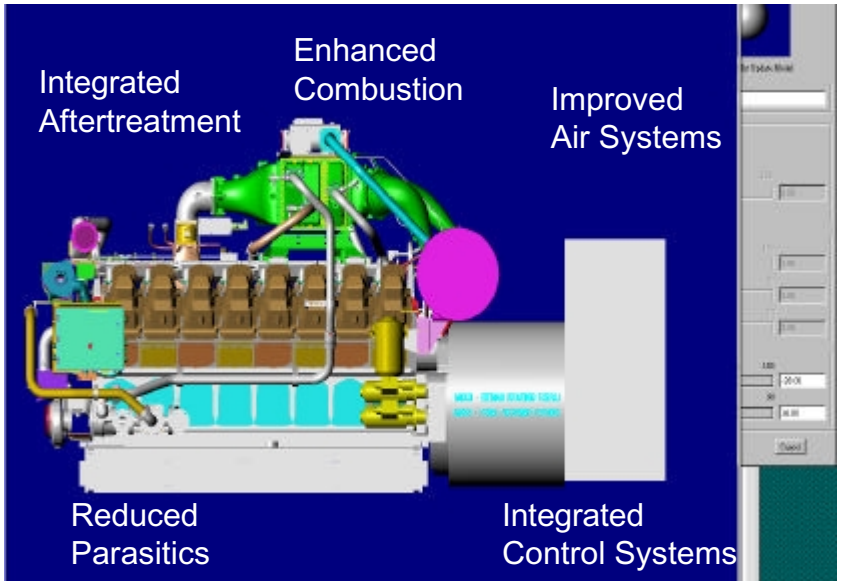
- **High Efficiency -** Fuel-to-electricity conversion efficiency of at least 50%
- **Environmental Superiority -** $NO_x < 0.1$ g/hp-hr (natural gas)
- **Reduced Cost of Power –** Energy costs, including O&M, at least 10% less than current state-of-the-art engines
- **Fuel Flexibility** – Adaptable to future firing with dual fuel capabilities
- **Reliability and Maintainability** – Equivalent to current state-of-the-art engines

DOE's Strategy is Based on Partnering



- Leverage limited resources
- Reduce financial and technical risks

DOE/Industry have Adopted an Ambitious Program Timeline



- DOE Workshop
- Industry Solicitation
- National Laboratory Call
- Awards to Industry Partners
- University Solicitation

1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010

Concepts

Development

Demonstrations

Commercialization

DOE Commitment

DOE R&D Program Initiated with Three Awards to Industry

- **Focused on research, development, and testing of advanced natural gas reciprocating engines**
- **Three awards totaling at least $15.0 million over 5 years:**
  - Caterpillar, Inc. (Lafayette, Ind.)
  - Cummins Engine Company, Inc. (Columbus, Ind.)
  - Waukesha Engine Division, Dresser Equipment Group (Waukesha, Wis.)

DOE Program Includes Four National Laboratory Projects

- **Focused on pre-competitive research activities that could have a significant impact in achieving the program goals**
- **Selected projects involving four national laboratories at $3.0 million over 3 years**
  - Sandia National Laboratory
  - Oak Ridge National Laboratory
  - Argonne National Laboratory
  - National Energy Technology Laboratory

DOE is also Including University Research in the Program

- **University solicitation initiated**
- **Evaluating university research projects focused on innovative/breakthrough technologies to address problems with:**
  - Ignition
  - Friction
- **$1 million over 3 years**

Recent Laboratory Visits Completed to Identify Additional Support Potential

- **DOE/industry team visited six major national laboratories (April - June 2001)**
- **Five technology categories covered:**
  - Combustion and ignition
  - After treatment
  - Air handling systems
  - Sensors and controls
  - Friction reduction

Team Identified Extensive Laboratory Capabilities in Advanced Engine Research

- **Industry team evaluated and prioritized 33 technology presentations**
- **Top one-third of list dominated by two technology categories**
  - After treatment
  - Sensors and controls
- **ARES report, including white papers, completed (July 3, 2001)**

DOE Welcomes Opportunities for Collaborative Research with CEC

- **Benefits**
  - Decrease technology development timeline
  - Leverage limited resources
- **Next Steps**
  - Identify areas of mutual interest and opportunities for cooperation
  - Establish communication mechanisms
  - Develop working relationship for DOE-CEC-industry programs